pooled plasma of the two test groups. As can be seen in Fig. 1, the concentration of carbon tetrachloride in plasma is substantially higher than in drinking water. In view of the lipophilic nature of carbon tetrachloride, our observations suggest that a bioaccumulation mechanism may be in operation, if drinking water is the only source of such materials. In addition, three isomers of dichlorobenzene (peaks c, d, and e of Fig. 1) were noted in the plasma but were not confirmed in the drinking water. Approximately 400 liters of New Orleans air were analyzed to determine if the atmosphere could be a major contributor of the halogenated compounds of plasma. No halogenated compounds were observed among the over 50 major organics evaluated by gas chromatography and mass spectrometry. The atmospheric samples were, however, rich in aromatic compounds.

At this point, one can only speculate about the origin of the organics in the drinking water and their relation to halogenated hydrocarbons in plasma. However, in view of the lipophilic nature of halogenated hydrocarbons and their occurrence in drinking water, it is not surprising that they might be found accumulating in blood or other body tissues.

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Retrograde Amnesia: Temporal Gradient in Very Long Term Memory following Electroconvulsive Therapy

Abstract. *A newly designed remote memory test has been used to assess the temporal dimension of prolonged retrograde amnesia. Patients given a course of electroconvulsive treatments for relief of depressive illness exhibited a temporal gradient of retrograde amnesia after five treatments. Memories acquired up to about 3 years before treatment were impaired, but memories acquired 4 to 17 years before treatment were not affected. The results suggest that the neural substrate of memory gradually changes with the passage of time after learning and that resistance to amnesic treatment can continue to develop for years.*

Retrograde amnesia is the loss of memory for events that occurred before some precipitating incident such as head trauma, drug injection, or electroconvulsive stimulation. Typically, as the interval between learning and amnesic treatment increases, the resulting amnesia is diminished. This phenomenon has usually been taken to mean that the neural substrate of memory changes or consolidates with the passage of time (*1*). It is not yet clear how long these changes can continue after learning. A large experimental literature based primarily on animal studies has suggested that the gradual increase in resistance to amnesic treatment may be complete within hours or days after learning (*1*). Yet in man the amnesic syndrome can affect memories acquired many years before the onset of amnesia (*2–4*), and sometimes memories acquired in the remote past appear to be less affected than those acquired more recently (*2*).

In such cases of prolonged retrograde amnesia, however, it is difficult to determine whether the amnesia is temporally graded or whether all memories are affected about equally. Sampling artifacts could easily lead to clinical impressions of a temporal gradient of retrograde amnesia (*3, 5*). Thus, when an interview covers a period of many months or years, questions about the remote past tend to sample a greater time interval and to be more general than questions about the recent past. In addition, memories sampled from different time periods are likely to be of different strengths. That is, questions about the remote past are directed at events that have proved resistant to forgetting, whereas questions about the recent past are directed at events that may be rapidly forgotten. Recently developed questionnaires about events and persons formerly in the news have been usefully applied to some aspects of the amnesic syndrome (*3, 4*), but these methods are also limited by the possible operation of sampling bias in the selection of questions.

A new remote memory test is available which may overcome these limitations by permitting equivalent sampling of events from different time periods (*6*). In this test the subject is asked to recognize the names of television programs that were broadcast nationally between 6 and 11 p.m. for a single season between 1957 and 1972. Program names were selected by a method designed to minimize sampling bias. In addition, popular ex-

posure to the programs selected for each time period was relatively similar, and names were apparently learned close to the time the programs were on the air (*7*).

We have used this remote memory test to evaluate the temporal dimension of retrograde amnesia in depressed psychiatric patients receiving a course of electroconvulsive therapy (ECT). We now report that five ECT treatments produce a temporal gradient of retrograde amnesia in very long term memory. Amnesia occurred for the names of television programs broadcast 1 to 3 years before treatment but not for programs broadcast 4 to 17 years before treatment. The loss appeared temporary, and memory was recovered somewhat by 1 to 2 weeks after the completion of treatment.

The subjects were 11 female and 5 male psychiatric inpatients, 22 to 66 years old (mean = 44), for whom a course of bilateral ECT had been prescribed for the relief of depressive illness. Only 2 of the 16 patients had received ECT before, and none had received ECT within the previous 2 years. Treatment was given three times per week on alternate days under barbiturate anesthesia (methohexital sodium, 60 to 90 mg) and atropine (0.8 mg), with full muscular relaxation (succinyl choline, 25 to 60 mg). Eight patients received all their treatments with an Offner (type 733) ECT machine (400 to 500 ma, 2 to 3 seconds), and eight patients received all their treatments with a Medcraft (B-24) machine (140 to 160 volts, 0.5 to 0.75 second).

The television test was constructed in a multiple choice format. Each question began, Which of the following was a TV show? and the correct answer was presented with three incorrect choices, randomly selected from a list of fabricated titles. The correct answer was always the name of a program that appeared for the first time in the autumn of one of the 16 years, 1957 to 1972, and that did not appear again in subsequent years. New programs beginning in the autumn of 1973 were not included, since at the time of testing it was not yet known which of them would be discontinued. Two equivalent forms of the test (A and B) were prepared, each consisting of 40 questions: 5 questions for each of the eight 2-year periods between 1957 and 1972. The order of the questions was random with respect to the time periods that they covered.

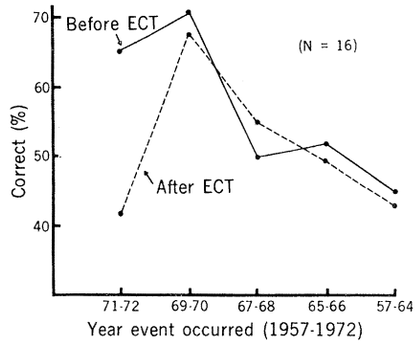

Fig. 1. A test of remote memory designed to eliminate sampling bias was administered to depressed psychiatric patients receiving a course of bilateral ECT. Testing was conducted before the first treatment and 1 hour after the fifth treatment. The ECT selectively impaired performance on questions covering the 1971–1972 period ($F = 12.8$, $P < .01$).

All patients took one form of the test 15 to 18 hours before their first ECT treatment and the other form 1 hour after their fifth ECT treatment. Half the patients took form A before form B, and half took form B before form A. In addition, each patient took the verbal portion of the Wechsler Adult Intelligence Scale before the first treatment and again 1 hour after the sixth treatment. Testing was conducted from January to June 1974.

Figure 1 shows performance on the television test before and after ECT. Before ECT, recognition was best for programs broadcast recently and poorest for programs broadcast many years ago. Performance for the entire period 1957 to 1972 was slightly, although not significantly, poorer than performance of a control group (*6*) of 56 hospital volunteers ($F = 2.9$, $P > .05$). Depressive illness apparently had little effect on test performance. After ECT, memory was unaffected for programs broadcast between 1957 and 1970 (*8*). However, memory was markedly impaired for the names of one-season programs that began in the autumn of 1971 or 1972, approximately 1½ to 2½ years before testing ($F = 12.8$, $P < .01$). For the period 1971 to 1972, performance dropped from 65 percent before to 42 percent after ECT. The result could not be explained by gross confusion or by an inability to maintain performance at a high level. First, verbal IQ was not affected by ECT (Table 1). Second, the score for 1971 to 1972 dropped to 42 percent after ECT, but scores for both 1967 to 1968 and 1969 to 1970 remained well above this value ($F = 4.2$ and 15.9, respectively; $P < .05$).

Table 1. Verbal IQ was tested before the first ECT and again beginning 1 hour after the sixth ECT. Scores were available for 14 of the 16 patients in the study, treatment having been discontinued after the fifth ECT in two cases. The values are means ± standard errors. Ranges are indicated in parentheses. Scaled scores for the arithmetic subtest are presented separately, since this subtest is reported to be particularly sensitive to cerebral dysfunction (*13*).

Test	Score	
	Before ECT	After ECT
Verbal IQ	102 ± 3.6 (81–126)	101 ± 3.2 (78–118)
Arithmetic subtest	8.6 ± 0.6 (6–13)	8.4 ± 0.6 (5–13)

We have considered the possibility that the anesthetic or other medications given at the time of ECT might have affected remote memory. The remote memory test was therefore given to eight depressed patients for whom a course of unilateral nondominant ECT had been prescribed (*9*). Unilateral ECT did not significantly change remote memory ($F = 0.2$, $P > .3$). For questions about 1971 to 1972, these patients averaged 69 percent correct before and 78 percent correct after ECT ($F = 1.2$, $P > .3$). Since unilateral and bilateral ECT differ only with respect to electrode placement, it seems reasonable to conclude that medication given at the time of ECT was irrelevant to test performance.

Thirteen of the 16 patients in the study were given both forms of the television test 1 to 2 weeks after completion of their course of ECT (5 to 13 treatments, mean = 7.6). For the period 1971 to 1972 these 13 patients averaged 67 percent correct before ECT, 45 percent correct 1 hour after the fifth ECT, and 60 percent correct at follow-up ($F = 7.0$, $P < .05$ for 45 compared to 67 percent). Apparently, remote memory, as measured by the ability to recognize the names of former television programs, had somewhat recovered 1 to 2 weeks after a course of ECT. It therefore seems reasonable to suppose that memories were not erased but that access to some memories was temporarily lost (*10*). These results, of course, do not preclude the possibility that remote memory for other kinds of material might recover more slowly after ECT (*11*).

Taken together, the results indicate that names presumably learned 1 to 17 years before ECT were differentially

sensitive to ECT. Memories acquired during the 3 years before ECT were impaired, but memories acquired before that time were not affected. The results therefore appear to confirm the hypothesis, originally formulated by Ribot (*12*), that the susceptibility of a memory to disruption is inversely proportional to its age. The validity of this conclusion depends, of course, on how well the remote memory test satisfies the requirements it was designed to meet. The most important of these is that names from each time period must be forgotten at the same average rate. Although this point is difficult to establish definitively with any retrospective method, considerable effort was made to meet this requirement by minimizing various kinds of sampling bias (*6*).

If resistance of memory to amnesic treatment can indeed increase over a period of years, then there must be two distinct consequences of the passage of time. First, material in memory becomes resistant to disruption over the years. Second, the same material becomes gradually more difficult to recall. Thus, names from 1971 to 1972 were remembered rather well, but were forgotten after ECT. Conversely, names from earlier time periods were remembered rather poorly, but were not affected by ECT. The neural substrate of memory apparently changes with the passage of time, such that resistance develops as forgetting occurs.

The frequent observation that retrograde amnesia can cover a time period of minutes, hours, or days has usually been interpreted to indicate that the memory storage process is labile for only a short period of time after learning and is then consolidated into a more stable state (*1*). The findings reported here indicate, however, that retrograde amnesia can sometimes cover a period of years. Accordingly, the development of resistance to amnesic treatment need not depend on the rapid transition from a labile to a stable memory process. The development of resistance can presumably depend on gradual changes in neural mechanisms that subserve enduring, relatively stable modifications in function.

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8. The results were submitted to a three-way analysis of variance with repeated measures and then to an analysis of simple main effects to make before and after comparisons for each 2-year time period [Q. McNemar, *Psychological Statistics* (Wiley, New York, 1962), pp. 323–333].
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10. We recently administered both forms of the television test to 16 persons who had received a course of 5 to 17 (mean = 9.9) bilateral ECT treatments about 6 months previously. Their test scores closely matched the scores of 56 control subjects (*6*). The two groups did not deviate from each other by more than 4 percent for any time period.
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Appraising Proposed Federal Standards for Water Resources Investment

In publishing articles on topics with respect to which most of its readers have no background, *Science* has a special obligation to select these articles carefully and to be certain that they and the references in them are balanced and accurate. A case in which these criteria have not been met is the recent article by Cicchetti, Davis, Hanke, and Haveman (*1*). The article is a critique of certain aspects of proposed federal standards for water resources planning and investment (*2, 3*). The weaknesses of the article are three. First, the authors do not make the reader aware of the context, including the scholarly background, from which the proposed new standards were derived. Second, on theoretical issues the authors do not adequately cite opposing views. The reader is thus not made aware that some of the authors' views are not universally, or even widely, accepted by scientists. Third, many of the references to the document reviewed by the authors are incomplete or inaccurate.

The standards under review by the authors are derived from a theory of public investment planning called multiobjective analysis. This theory was first set out in the classic *Design of Water-Resource Systems* (*4*). A more recent version can be found in *Guidelines for Project Evaluation* (*5*). In this latter work multiobjective planning is recommended for all economic sectors, not just for water resources. According to multiobjective theory, public projects should be designed explicitly in terms of a wide range of social, economic, and environmental objectives. This is a generalization of the traditional "economic" benefit-cost analysis that the proposed standards were meant to supplant. The authors neither describe this major theoretical development in project planning nor do they indicate that it provides the intellectual foundations for the proposed new standards; as a result, it is difficult for the reader to judge the